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EXPERIMENTAL RESEARCH OF THE INFLUENCE OF UNDERPRESSURE ON FORCE VALUES AQUIRED IN GRANULAR BEAMS BENDING TESTS

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ABSTRACT: Former works of authors ([1], [2], [3], [4], [5]) were devoted to preliminary probes of applying Chaboche's viscoplastic constitutive law for describing of non-linear properties of specimens made by granular materials under special conditions. Those are: air thigh sleeve with internal underpressure.

Searching for an alternative form of using a loose material, possibilities of designing of provisional shapes of granular systems, when they are placed is special conditions are worth mentioning. Mainly attractive is placing them in a thigh encapsulation, where so called underpressure is generated in next stage. Such a solution gives wide ranges of opportunities for technical applications which is already used in beverages market, also in damping of noise and vibrations field, architecture, medicine etc..

In this paper we focused on determining the influence of underpressure, generated inside the specially shaped elements on force values obtained in bending tests of granular beams.

Main problems connected with preparation of such laboratory tests will be discussed. The main objective of this paper is to proof the magnitude of so called underpressure on the macroscopic mechanical properties of elements built on the basis of granular materials.
Lot of experimental results will be presented and discussed in details.

KEY WORDS: Granular structures, experimental research, granular beams, bending

1. INTRODUCTION

At the beginning, the term „granular beam" has to be introduced. Testing specimen discussed in this paper is composed on the basis of granular materials, surrounded by a hermetic wrap, made of soft plastomer, where so called under pressure is generated.

Taking advantage of such a plastic granular mass enables for lot of technical applications. The most interesting seems to be possibility of controlling the main strength properties of granular conglomerates by increasing (decreasing) the value of internal underpressure. Previous works of authors ([1], [2], [3], [4], [5]) have focused on detailed investigation of this parameter influence on such parameters as Young modulus or a proof stress. In the strength experiments, specially designed granular sample has been designed.
Currently discussed paper is only a part of a wide experimental research on granular structures, placed in a hermetic space with underpressure. This time only bending results of granulate beam will be discussed. The controlling factor which enables for changing mechanical properties of granular structure in quite a wide range is the value of internal underpressure.

2. OBJECTIVES

The main objective of this paper is discussion of problems encountered during the measurement cycle and those related to conducting granular beam bending experiments. Also very important aim is presenting direct experimental results confirming the influence of underpressure on the forces necessary for bending the granular beam by the previously defined value. Hitherto existing experimental results proved the stiffening of granular structures during increasing the internal underpressure. All of carried out experiments on granular materials in special conditions are related to the cylindrical material sample. Problems of shape and dimensions selection of granular specimens have been discussed in details in former work of authors, for example in [6], [7] or [8]. In this paper this topic will not be discussed. Although authors did their best to establish the representative shapes and dimensions of granular sample, so called scale effect is still an open problem for granular conglomerates. This phenomenon causes variations in acquired experimental in accordance with the initial volume of the testing specimen.

3. EXPERIMENTS

Here again it is worth mentioning that the term *granular structure* is considered as a homogenous material composed on the basis of: loose material, tight plastomer envelope and additionally undrepressure, which the main objective is aggregating of mentioned components. There is a lack of any literature related to conducting granular beam bending experiments, so presented in this paper laboratory tests could be named innovatory. In the paper four different kinds of granular materials are investigated: polypropylene, polystyrene, polymethacrylate and ABS. In the further part of the paper such symbols as: PP, PS, POL and ABS will be used respectively. The range of generated underpressure values varied form 0,01 [MPa](almost atmospheric pressure) to 0,09 – vacuum like pressure. The structural scheme of the granular beam sample has been depicted in Fig.1. It also takes into consideration additional devices such as vacuum pomp, manometer and filter. Its purpose is to provide and maintain the previously selected pressure value during the whole experiment.

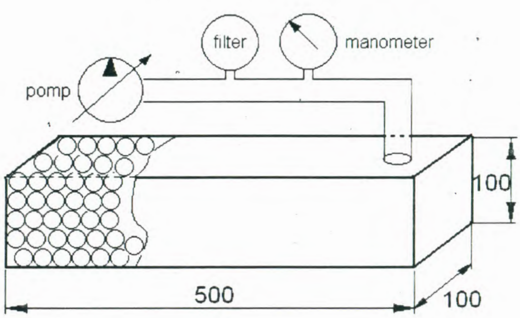

Fig. 1: Structural scheme of the granular beam with additional devices taken into consideration

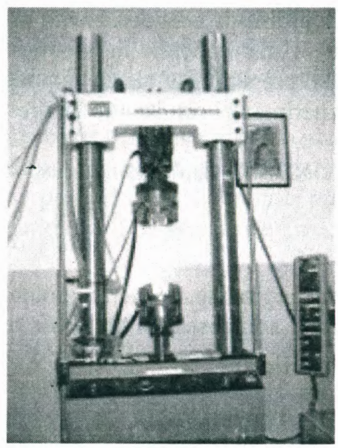

***Fig:* 2** Universal testing machine MTS 809

Depicted in Fig. 1 encapsulation, surrounding loose granular material, ought to be, besides tightness, also resistant enough, to withstand friction forces, especially considerable when high underpressure values are generated inside the specimen. Obviously even a small perforation of the encapsulation causes damage of the whole sample.

Also an assumption has been made, that dimensions of the sample are much larger then dimensions of a single grain; ($V_{sample} >> V_{grain}$).

3.1 Filling ratio

All of considered granular materials have comparable shapes of a single grain. They are cylinders having diameter about 1 mm and 3 mm length. Geometrical features of a loose materials have been totally neglected in this paper so their influence on macroscopic properties of the system is not discussed.Only porosity of considered granular media has been taken into considerations. Porosity (N) is assumed to be a free volume factor, do not filled by granular media, to the total volume of the container (the external volume of the granular beam envelope – Fig. 1)

$$N = \frac{V_w}{V} = \frac{V - V_s}{V}, \; V_s = \frac{m_s}{\rho_g} \tag{1}$$

where:

V_w - free "intermolecular" space,
V_s – loose material volume,
V – total volume,
m_s – granular materials mass,
ρ_g - grain's density.

Maintaining the constant value of the porosity aimed at elimination the influence of non-uniform filling phenomenon on acquired experimental results. In all experimental research, the porosity coefficient N was constant and equal N=0,6.

Satisfying N=const. condition amounts to determining the density of granular materials. In the next step it is reduced to pouring in the previously measured mass of granular media to the initial cylindrical form of the envelope.

Significance of the filling ratio constant value is especially important during comparing obtained experimental results for different granular materials. Force values, necessary to reorganize granular concrete, consisting in its densification, are disproportionate to those, which are essential to produce elastic (plastic) deformations of grains.

Tested beams have been performed on the basis of the same envelope material which was a soft plastomer. In the wrap a suitable valve has been mounted, which enables for pulling out the air from the interior of the sample to the previously intended value (Fig. 1).

Laboratory tests have been conducted on the standard testing machine MTS 809 (Fig. 2). Beams have been mounted in special handles enabling their bending (Fig. 4).

In experimental research the lowest measuring capacity has been taken into consideration. Measuring system, thanks to advanced controlling electronics and computer software enables for the automatic zero correction. Recorded data was in the numerical form.

In the experimental process, besides maintaining the constant value of the filling ratio, also constant values of measuring parameters for each cycle have been provided (initial conditions, the same scheme of the measuring cycle, etc.)

Single measuring cycle with one kind of granular material and for chosen value of internal underpressure included such tasks as:

- Filling the granular form by the precisely measured mass of granular materials,
- beam forming (Fig. 3),
- mounting of the sample in special handles (Fig. 4),

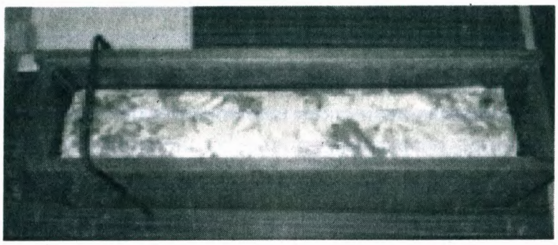

Fig. 3 Beam forming

Fig.4 Mounting of the sample in special handles

- joining the sample to the vacuum pomp by the flexible hose,
- activating the vacuum pomp and generating intended value of internal underpressure,
- zeroing the testing machine,
- carrying out of experiments.

In this part of the paper, the following measuring cycle conditions have been taken into consideration:

Samples filled with four different kinds of granular materials, bended with a constant quasi static strain rate, which is related to beam deflection by o Δl = 15 [mm] in time t = 90 [s]. Three separate experimental series of each experiment have been conducted.

4. RESULTS

In following figures, typical experimental results of granular beam bending have been depicted. As it was previously mentioned, four different types of granular materials have been taken into consideration. In Fig. 5-8, forces necessary to bend a granular beam versus displacement have been illustrated. On the basis of Fig. 5-8, it is easy to conclude, that considered granular structures in special conditions have strongly non-linear properties. Additional feature of such structures is a viscoplasticy. It is not observable in experiments presented in this paper, but former works of authors [9] or [10], have revealed such a phenomenon. Viscoplastic properties of materials leave an open problem related to defining the quasi-static strain rate for a new, tested structures. This problem is quite complex and will not be discussed in this paper, although ones can find in for example in [4], [6] or [7].

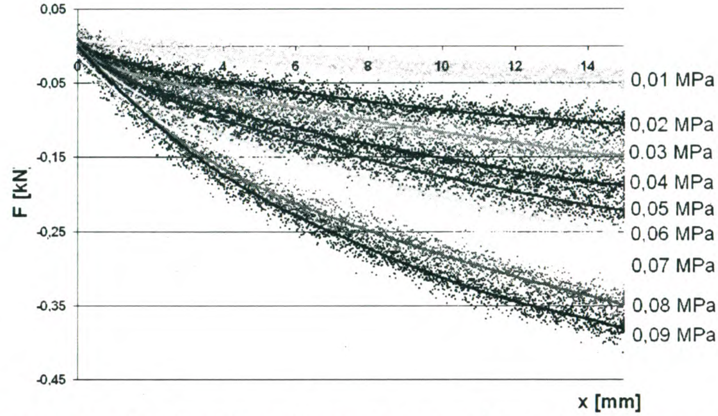

Fig. 5: Experimental results of bending of granular beam, filled with ABS granular material, for various range of generated underpressures (0,01-0,09 [MPa])

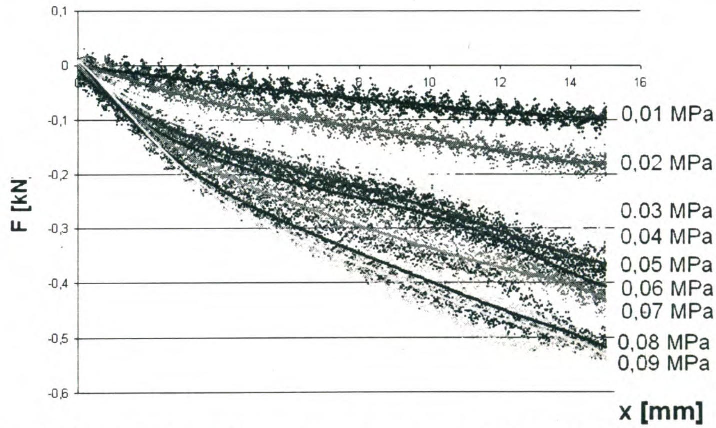

Fig. 6: Experimental results of bending of granular beam, filled with polymethacrylate granular material, for various range of generated underpressures (0,01-0,09 [MPa])

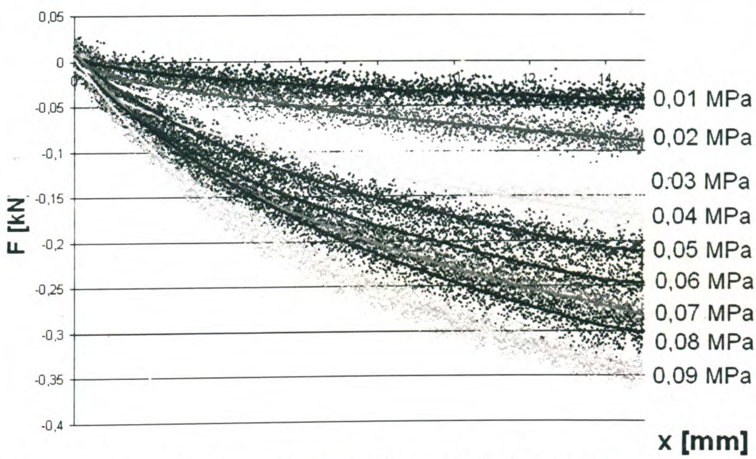

Fig. 7: Experimental results of bending of granular beam, filled with polypropylene granular material, for various range of generated underpressures (0,01-0,09 [MPa])

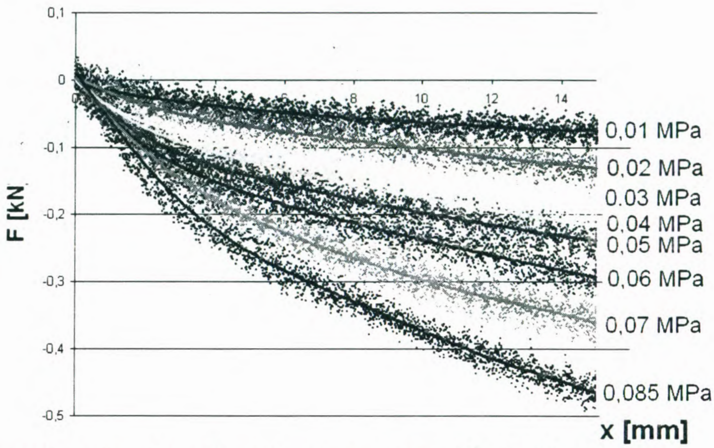

Fig. 8: Experimental results of bending of granular beam, filled with polystyrene granular material, for various range of generated underpressures (0,01-0,085 [MPa])

Interpolating curves are depicted on the background, which are three separate experimental series. Interpolation process was achieved using commercial software SIGMAPLOT [11], taking advantage of Marquarda-Lerenberga algorithm [12].

5. CONCLUSIONS

On the basis of results depicted in fig. 5-8, the following conclusions can be made:

- curves characterizing bending process have similar shape for all considered kinds of grains. It reflects strongly plastic properties of granular structures in special conditions. It is at the same time confirmation of former authors observations (uniaxial tensile and compression tests of cylindrical samples [1], [2], [3], [4], [5]).
- F=f(x) curves have two clear stages. In the first, coefficient $\frac{dF}{dx}$ values are quite high. In the second it stabilizes. As an exception, result of polymethacrylate granular beam bending at 0,06 [MPa] could be introduced (fig. 6). This result in comparison with other should be rejected.
- large scatter of experimental results is caused by insufficiently small range of the testing machine. This phenomenon is particularly visible for lower values of underpressure. Although applying identical initial conditions for all of conducted tests enables for evaluating the influence of underpressure on acquired results
- increasing underpressure values causes a clear increasing of force values necessary to deflect granular beam. Differences in those values reach even the 500% level (fig. 6),
- although in all experimental results similar shapes and dimensions of granular grains have been applied, a clear differences in obtained results depending on a type of single grain's material is observed. Global mechanical properties of granular structures, placed in a hermetic space with underpressure, considerably depend on the king of material

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